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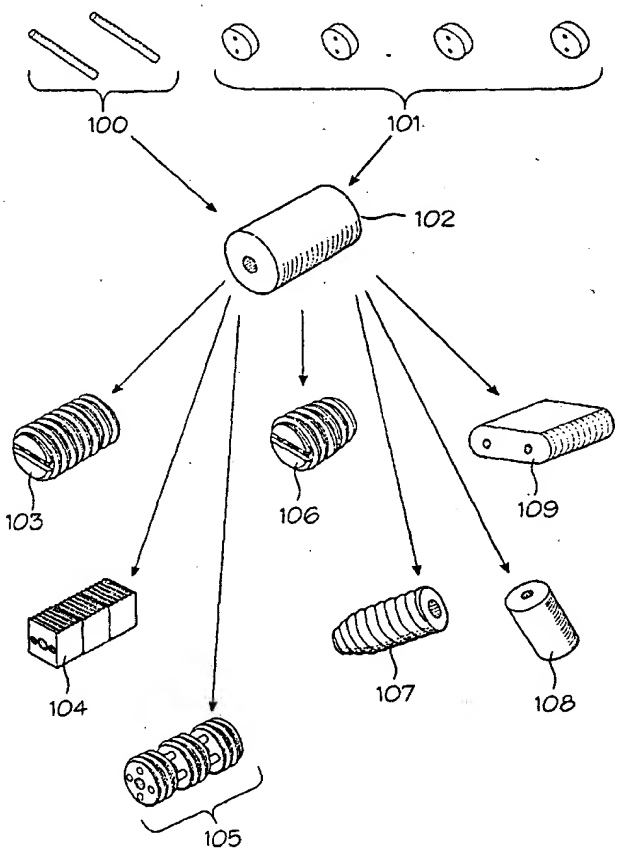

(57) Abstract: This invention provides a method for manufacture of autograft, allograft and xenograft implants which comprises assembling such implants from smaller pieces of graft materials to form a larger graft implant product.

WO 01/78798 A1

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TITLE OF THE INVENTION
ASSEMBLED IMPLANT

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of pending provisional application serial number 60/181,622, filed February 10. 2000, pending, and of application serial numbers 09/191,132, filed on November 13, 1998, pending; and of 09/378,527, filed on August 20, 1999, pending; and of 09/370,194, filed on September 7, 1999, pending; 29/123,227, filed May 12, 2000, pending; the priority of all of which is claimed herein under 35 U.S.C. Section 120.

FIELD OF THE INVENTION

This invention relates to implants and methods for their preparation wherein components of the implant are assembled from constituent pieces to produce a complete implant.

BACKGROUND OF THE INVENTION

In the field of medicine, there has been an increasing need to develop implant materials for correction of biological defects. Particularly in the field of orthopedic medicine, there has been the need to replace or correct bone, ligament and tendon defects or injuries. As a result, there have emerged a number of synthetic implant materials, including but not limited to metallic implant materials and devices, devices composed in whole or in part from polymeric substances, as well as allograft, autograft, and xenograft implants. It is generally recognized that for implant materials to be acceptable, they must be pathogen-free, and must be biologically acceptable. Generally, it is preferable if the implant materials may be remodeled over time such that autogenous bone replaces the implant materials. This goal is best achieved by utilizing autograft bone from a first site for implantation into a second site. However, use of autograft materials is attended by the significant disadvantage that a second site of morbidity must be created to harvest

autograft for implantation into a first diseased or injured site. As a result, allograft and xenograft implants have been given increasing attention in recent years. However, use of such materials has the disadvantage that human allograft materials are frequently low in availability and are high in cost of recovery, treatment and preparation for implantation. By contrast, while xenograft implant materials, such as bovine bone, may be of ready availability, immunological and disease transmission considerations imply significant constraints on the ready use of such materials.

In view of the foregoing considerations, it remains the case that there has been a long felt need for unlimited supplies of biologically acceptable implant materials for repair of bone and other defects or injuries. This invention provides a significant advance in the art, and largely meets this need, by providing materials and methods for production of essentially any form of implant from component parts to produce assembled implants.

In recent months, there have appeared several patents and patent publications which address similar or identical considerations to those to which the present invention disclosure is directed. Specifically, reference is made to PCT publication WO00/40177, which published on 13 July 2000, the disclosure of which is hereby incorporated by reference as if fully set forth herein.

In addition, reference is made herein to US Patent 5,899,939 to Boyce, which issued on May 4, 1999, the disclosure of which is hereby incorporated by reference as if fully set forth herein.

Finally, reference is made herein to US Patent 6,025,538 to Yaccarino, which issued on February 15, 2000, the disclosure of which is hereby incorporated by reference as if fully set forth herein.

SUMMARY OF THE INVENTION

This invention provides a method for manufacture of autograft, allograft and xenograft implants which comprises assembling such implants from smaller pieces of graft materials to form a larger graft implant product.

Accordingly, it is one object of this invention to provide a method for assembly of multiple bone implant shapes from smaller bone implant pieces.

Another object of this invention is to provide assembled bone implants.

Another object of this invention is to provide a method whereby otherwise wasted tissue may be used in the production of useful orthopedic implants.

Further objects and advantages of this invention will be appreciated from a review of the complete disclosure and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Attached to this invention disclosure are a large number of sketches which demonstrate a wide variety of assembled implants which may be prepared and used according to this invention.

Figure 1 is a flow chart showing the formation of various sub-component parts of an assembled implant according to this invention, from which assembled implants and a kit comprising these parts may be formed according to the disclosure of this invention.
Figure 2 provides a schematic of an assembled implant according to this invention.
Figure 3 provides a schematic of an assembled implant according to this invention.
Figures 4-7 provides a schematic of an assembled implant according to this invention.
Figures 8-9 provides a schematic of an assembled implant according to this invention.

Figures 10-14 provides a schematic of an assembled implant according to this invention.
Figures 15-18 provides a schematic of an assembled implant according to this invention.
Figure 19 provides a schematic of an assembled implant according to this invention.
Figure 20 provides a schematic of an assembled implant according to this invention.
Figure 21 provides a schematic of an assembled implant according to this invention.
Figure 22 provides a schematic of an assembled implant according to this invention.
Figure 23 shows the assembly of a dowel from component pieces.
Figure 24 shows the reinforcement of an implant using a cortical bone pin.
Figure 25 shows the reinforcement of an implant using a cortical bone pin and a cortical bone disk.
Figure 26 shows the reinforcement of cancellous bone implants using a plurality of cortical bone pins.
Figure 27 shows the formation of an assembled implant comprising soft and hard tissues.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Currently, autograft, allograft and xenograft products are produced as solid, continuous materials. For example, bone dowels (see US Patent 5,814,084, hereby incorporated by reference), Smith-Robinson cervical spine implants, iliac crest grafts, and the like are harvested and machined from single, continuous pieces of bone. The present invention provides methods for manufacture of autograft, allograft and xenograft implants by assembling such implants from smaller pieces of graft materials to form a larger graft implant product. As a result, increased utilization of valuable implant materials is achieved, thereby more effectively meeting the ever-increasing demands for graft implant materials. In addition, greater flexibility is achieved in the types and shapes of implant materials is achieved. Essentially, any implant piece that may be required may be formed according to the present invention, and orthopedic surgeons may be provided with kits of assemblable parts which may be formed in the course of a surgical procedure to precisely meet the needs of a given patient or procedure. In yet another aspect of this invention, existing graft products may be strengthened or reinforced by assembly of different types of

graft materials into an assembled product. One example of such a reinforced product is a cancellous wedge, block, dowel or the like into which is inserted reinforcing pins of cortical bone. As a result, those skilled in the art will understand from this disclosure that different sections of tissue may be assembled to make a complete graft implant. Furthermore, this invention provides for the product of assembled implants comprising any one or combinations of allograft materials, autograft materials, xenograft materials, synthetic materials, metallic materials and the like. Furthermore, the assembled implants or the component pieces which are combined to form the assembled implant may be pre-treated or treated after assembly to incorporate any desired biologically active or inert materials. Thus, for example, in an assembled bone dowel implant according to this invention, the assembled bone dowel comprises segments of cortical bone pinned to each other by means of cortical bone pins. Prior to assembly or after assembly, the graft materials are soaked, infused, impregnated, coated or otherwise treated with bone morphogenetic proteins (BMP's), antibiotics, growth factors, nucleic acids, peptides, and the like.

It will be appreciated that variously shaped wafers, blocks, rings, washer-shaped bone pieces and the like may be affixed to each other in any secure and biologically acceptable manner. Preferably, the assembled pieces of bone are affixed to each other by means of pins, screws, rods, interference fit, threaded fits, key-way fit, and the like made from cortical bone. These fixation pieces are machined in a CNC lathe or the like to appropriate dimensions and are then threaded into mating holes tapped in the pieces to be assembled, or are pressed into drilled holes through adjacent pieces to be assembled by a pneumatic press or the like. In this fashion, very strong and tightly fitted pieces of implant materials may be joined and implanted. The assembled pieces may first be machined to desired dimensions and shapes, prior to assembly, the assembled implant may be machined, or both.

As noted above, the implant according to this invention may comprise an assembled cancellous block, dowel or the like, harvested from the iliac crest or another suitable site.

As is known in the art, due to the wafer-like structure of cancellous bone, such grafts have low load-bearing characteristics. There exist reports in the literature of instances of extrusion, expulsion or collapse of iliac crest wedges, Cloward Dowels, and the like when utilized, for example, in spinal fusions. Nonetheless, use of cancellous bone is preferable over use of cortical bone implants, since cancellous bone is more osteoconductive than cortical bone. According to this invention, a Cloward Dowel, iliac crest wedge, or cancellous bone block, dowel or the like is reinforced by insertion therein of cortical bone pins. According to the method of this invention, cortical implants may also be reinforced by insertion therein of cortical bone pins, including when an assembled implant is prepared comprising different segments of cortical bone, cancellous bone or both. Insertion of the reinforcing pins provides an implant with multiple load-bearing pillars. The pins may be made to protrude from the surface of the implant to engage with inferior, superior or both surfaces of bone between which the implant is inserted. Thus, in a spinal implant, pin protrusions may be employed to created contact between the implant and the vertebral bodies, thus preventing extrusion and reinforcing a secure fit of the implant between adjacent vertebrae. We have, surprisingly, found that cortical pins of about 4.5 mm in diameter may each support a load of up about 2700 newtons (160 Mpa). Thus, according to the method of this invention, multiple pins may be inserted into an implant to produce a load-bearing capacity of known proportions (e.g. 10,000 newtons by insertion of five pins).

A further advantage of this invention is that it permits use of tissues that are not currently amenable to standard autograft, allograft or xenograft harvesting and processing procedures, such as ribs, metatarsal bone and the like. In addition, useful implant materials may be harvested and produced from otherwise un-useable donor tissues. In addition, due to the different nature of various segments of bone that are incorporated into the assembled, reinforced implants of this invention, various shaping methods aside from CNC lathe or other known procedures may be applied to different segments of the implant. Thus, a cancellous portion of bone implant may be compression molded, and then affixed to other portions of cortical or cancellous bone machined according to different or similar principles. In addition, due to the ability provided by this invention to assemble implant

pieces, implants of unusual sizes and dimensions may be prepared and machined. Thus, implants of 100 mm in size could be machined, for example, for corpectomies, when otherwise bone stock for manufacture of such implant dimensions would not be available.

In view of the present disclosure, it will be appreciated that this invention provides a wide variety of assembled implants and implant parts: dowel shaped implants comprising assembled dowel segments, between about two to about ten segments, pinned together by one or more cortical bone pins. The assembled segments may closely abut each other or may be spread apart from each other. Such implants may be prepared by harvesting disks of cortical bone, drilling and optionally tapping holes therein, and inserting shafts of cortical pins therethrough, or therein, optionally by threading portions thereof for torquing into optionally tapped holes. The thus produced dowels may be tapered or have parallel sides. In addition, dowels which are harvested as a cross-section across the intramedullary canal of a long bone, as in US Patent 5, 814,084, which might otherwise not pass production specifications, due to penetration of one outside wall into the intramedullary canal, may be completed by insertion therein of a cortical pin. Likewise, where a sidewall is otherwise considered to be too narrow, a "doughnut" of bone may be affixed to the sidewall by means of a cortical pin. A longer dowel may be prepared by affixing two dowels to each other. A posterior longitudinal interbody fusion implant (PLIF) may be machined from a single piece of cortical bone, or be assembled from two pieces of bone which are affixed to each other by means of a cortical pin. A bone screw may also be prepared according to the method of this invention by affixing multiple pieces of cortical bone to each other with a cortical bone pin, and then machining a thread on the exterior of the assembled bone pieces. It will further be appreciated from this disclosure that different portions of the assembled implant may be demineralized, to achieve a level of elasticity or compressibility not otherwise present in cortical or cancellous bone. Different portions of bone may also be retained on a shaft by means of a cotter-pin type device.

In addition to assembled implants, instruments may be conveniently prepared according to the methods of this invention which may be utilized for insertion of other implants. In one

embodiment of this invention, therefore, an implant driver is produced wherein the driving mechanism itself is formed from assembled cortical pins which protrude into mating recesses in an implant device. The instrument may be torqued to adequate loads to induce implantation of spinal implants and the like.

In developing the various embodiments of the present invention, one technical issue of merit is the need to develop a process whereby donor tissue, whether hard or soft tissue, allograft or xenograft tissue, may be treated in such a fashion as to eliminate the possibility of cross contamination between tissue segments obtained from different sources. While it is possible to practice the present invention to advantage using tissue obtained from a single screened donor, the real economies of scale and commercially viable application of the present technology is best realized by implementation of an efficient and reliable tissue decontamination process. Ideally, the process is one which permits multiple segments of soft or hard tissue to be treated simultaneously so that a stock of materials for assemblage of implants according to the present invention is facilitated. Accordingly, on preferred method for treatment of tissue, disclosed in PCT publication WO 00/29037, the disclosure of which is hereby incorporated herein by reference as if fully set forth herein (and priority of the US Patent filings which gave rise to this application is hereby claimed for that purpose). Accordingly, in this aspect of the invention, a process is claimed whereby an assembled allograft or xenograft tissue implant is prepared by treating the tissue in a closed container in which different cleaning solutions are contacted with the implant segments, either before or after assembly and machining into the final implant form, either in the presence or absence of sonication, with rapid oscillation of pressure in the closed container, to achieve deep cleaning and interpenetration of cleaning solvents into the interstices of porous implants or tissues. Solutions including, but not limited to detergent solutions, peroxide solutions and the like are used in such procedure, and terminal sterilization with gamma irradiation, gaseous sterilants known in the art or other terminal sterilization procedures known in the art are employed to ensure safe implantation of the assembled implants according to this invention.

Referring now to figure 1, there is shown a flow-chart representing various elements that may be processed and assembled according to this invention. Cortical bone pins **100** are used to assemble a series of bone disks **101** into a pre-part **102** which is then machined into a series of final products: Threaded dowels, **103**; small blocks **104**; unique shapes, **105** such as a "wedding-cake" like shape wherein disks bearing threads are spaced apart from each other leaving voids **105'** into which additional materials may be inserted, with the disks retained in fixed relation to each other by means of the through pins **100**; tapered dowels **106**; screws **107**; smooth cylinders **108**; or large blocks **109**. From this figure, it will be appreciated that a central concept relevant to the present invention is the ability to machine smaller parts of tissue, specifically bone tissue, such as cortical bone, cancellous bone, cortical-cancellous bone, portions of which may be demineralized (see, for example, US Patent 6,090,998, hereby incorporated herein by reference for this purpose), and assemble these portions of tissue using, preferably, cortical bone pins. The assembled tissue pieces may be machined prior to assembly, and then, upon assembly, a complete implant is ready for implantation. Alternatively, the tissue pieces may first be assembled, and the assembled pieces may then be machined into any desired final form. The order of assembly and machining will be determined by the specific forms of implant required for a particular application. In figure 1, a series of pre-machined tissue forms are disclosed, which may conveniently be included in a kit for use as needed by an orthopedic surgeon. Thus, for example, where a particular implant of specific dimensions is required, the surgeon is able to select pre-shaped implant segments to fill a particular geometric space and shape in the spine of an implant recipient. Numerous permutations and combinations of implant pieces for assembly are possible, based on the pre-machined assemblable implant pieces included in such a kit, and those skilled in the art will appreciate that the skilled orthopedic surgeon will be able to create implants as needed when supplied with such a kit. Thus, a preferred kit includes disks of bone, cortical bone, cancellous bone, allograft or xenograft, also referred to herein as "washers" or "doughnuts" such that a center hole is provided for press-fitting or screwing on of the disks to a cortical bone or synthetic or metallic shaft or pin. The disks may be demineralized, mineralized, or partially demineralized. Also desirable in such a kit are plugs of cortical bone, cancellous

bone, or cortical-cancellous bone, including at least one through hole, and optionally more than one such through hole, for insertion of pins therethrough. Ovals, squares, rectangles and irregular shapes may also be provided in certain kits for specific applications. It will further be appreciated, based on the present disclosure, that inclusion of a bone paste, such as that disclosed in WO99/38543, hereby incorporated by reference, may be beneficial for filling any voids that remain, and to implant with the assembled implant, osteogenic material, (i.e. osteoconductive material, Osteoinductive material, or both, as well as material that assists in adhering the implant to the site of implantation). Further, a molded implant may be combined with the assembled implant of this invention. A preferred molded implant for orthopedic applications is disclosed in PCT publication WO 00/54821, the disclosure of which is hereby incorporated by reference.

With reference to figure 2, there is shown two machined bone pieces, **T** and **Z** each of which bear external threading **X** and holes **Y** into which pins **A** are inserted to form the assembled graft **200**. As can be seen, the assembled graft **200** comprises a void, **201** into which osteogenic material may be inserted prior to or after implantation. The pins **Y** may be metal pins, but preferably are pins machined from cortical bone. This enables the entire implant to remodel into autogenous tissue over time, such as vertebral bone, when the implant **200** is inserted into the intervertebral space. The graft **201** is also shown with a groove, **202** in which a driver may be inserted to provide rotational torque for insertion of the implant. An instrument attachment hole, **203**, is also provided, to ensure that the implant remains securely on the head of the driver means in the process of surgical implantation. Naturally, those skilled in the art will appreciate that the segments **Z** and **T** may be brought into close abutment with each other, thereby eliminating the space **201**. In that event, the length of the pins **A** would be modified to prevent unnecessary protrusion, although in some applications, protrusion may be useful when driving the implant **200** into place. It will also be appreciated that the number of pins used, while represented as two in this figure, may be fewer or more in number, depending on the particular application, the extent of torsional or compressive loads, and the like anticipated to be experienced by the implant once *in situ*.

Figure 3 shows an implant assembled from three principal segments **F, D,** and **E**, which are held together by pins **300**. In this implant, the waffle-shaped structure of implant segment D is intended to represent the use of cancellous bone, which is abutted on either side by cortical bone, which forms segments **F** and **E**. The fully assembled implant is shown in figure 4, while figures 5, 6 and 7 show end-on views, and cross sectional views A-A and B-B, respectively. Those skilled in the art will appreciate from this disclosure that segment **F**, segment **D**, or segment **E** may be demineralized according to methods known in the art. Likewise, all of these segments may be demineralized. Where a flexible implant is required, the implant may be assembled, and the entire implant may be demineralized.

Figure 8 shows an embodiment of this invention wherein rectangular bone segments **N** and **G** are assembled into implant **900**, shown in figure 9. Features **901** and **902** which comprises ridges, teeth, or other external features are machined into the superior and inferior faces of the implants in order to assist in retention of the implants once placed *in situ*.

Figures 10-14 show the assembly of elements **J, H,** and **I** into implant **1100**, shown end-on, in cross-section A-A and B-B, in figures 12-14, respectively. As can be seen, bone element **H** is shown with a waffle-like structure, to represent that this element may be cancellous bone, demineralized bone, a polymer composite, such as poly-L-Lactic acid, polyglycolic acid, or the like. Features **1101** and **1102** represent external grooves or teeth machined into the superior and inferior surfaces of the implant to assist in retention of the implant once placed *in situ*.

Figures 15-18 show the assembly of elements **M, K,** and **L**, each of which is a substantially cubic bone element, using pins **1500**. Figure 17 is a top view, showing cross section A-A, represented in figure 18, with the final assembled implant **1600** shown in figure 16.

Figure 19 shows a "Wedding-Cake" design of an implant **1900** assembled from units **A-C**, pinned together by pins **a-c**. Void area **1901** is available for filling with osteogenic materials.

Figure 20 shows implant **2000** which is an assembled Cervical Smith Robinson implant similar to that shown in PCT publication WO99/09914, hereby incorporated by reference, except that this implant is fashioned from a series of assembled bone pieces **2001** and machined into the desired final shape.

Figure 21 shows implant **2100** assembled from two cortical bone pieces and one cancellous bone piece, and pinned together. The implant has an anterior height **H1** which is smaller than posterior height **H2**, which permits retention of correct spinal lordosis upon implantation, for example, in a posterior lumbar intervertebral implant fixation procedure. Superior and inferior features **2101, 2102** prevent expulsion of the implant once place *in situ*.

Figure 22 shows an implant **2200** assembled from a series of sub-implant pieces **2201**. The implant may contain cancellous bone **2202** segments, as well as cortical bone **2203** segments and cortical bone pins **2204**.

Figure 23 shows the formation of a tapered dowel **2300** by assembling "doughnut" or "disk" or "washer" shaped bone pieces **2301** on a cortical bone shaft **2302** by using washer pieces of differing diameter. This figure only shows two disks, but a continuous dowel is formed by using disks of a graded diameter between each end of the cortical bone shaft **2302**. In figure 24, figure 24A shows a bone dowel in which one sidewall of a bone dowel **2400** such as that disclosed and claimed in US Patent 5,814,084, hereby incorporated by reference, is "out of specifications" due to being too narrow or absent. This is repaired in figure 24B according to this embodiment of the invention by incorporation of an allograft or xenograft cortical bone pin **2401**, to form a complete bone dowel. In this manner,

valuable biological material which might otherwise be unusable for a particular application may be salvaged for use by employing the methodology of this invention.

In figure 25, a similar procedure for salvaging a dowel **2500** is shown whereby a pin **2501** is driven through the center of the dowel **2500** to reinforce the dowel longitudinally. Furthermore, where an endcap **2503** of the dowel is "out of spec" for being too narrow, the endcap is reinforced by press-fitting a cortical bone disk **2502** onto the end of the pin **2501**.

In figure 26, a series of cancellous bone implants **2600** are reinforced by inclusion therein of a series of cortical pins **100**. Each cortical pin of a 2 mm diameter has been found to support approximately 2000 newtons of axial compressive load. Accordingly, cancellous bone implants of essentially any desired height and compressive strength may be assembled in this manner by affixing several layers of cancellous bone with cortical bone pins. Naturally, based on this disclosure, those skilled in the art will appreciate that other materials may be included in such a "sandwich" of bone materials. The cancellous bone may be soaked in a solution containing growth factors, such as, but not limited to, bone morphogenetic proteins, fibroblast growth factors, platelet derived growth factor, cartilage derived morphogenetic proteins, stem cells, such as mesenchymal stem cells, osteoprogenitor cells, antibiotics, antiinflammatory compounds, anti-neoplastic compounds, nucleic acids, peptides, and the like. Those skilled in the art will also appreciate that layers of cortical bone may be included, layers of biocompatible synthetic polymers and the like may also be included in the stacked bone implant. Various shapes may also be built upon, using for example, circles, ellipses, squares, and the like, as necessary for a given application.

In a further aspect of the present invention, the assembled implant is driven by cortical pins to seat in an implant site, using a driver that engages cortical bone pins with purchase sites on the implant. Thus, for example, not meant to be limiting, the driver may comprise a handle with projecting cortical pins which engage with holes in the assembled allograft, thereby providing a site for torquing the implant into position.

In a further embodiment according to this invention, assembled cortical bone blocks, or cortical cancellous bone blocks are assembled in combination with wedged or pinned soft tissue, such as tendon, ligament, skin, collagen sheets, or the like, to create grafts similar to naturally occurring tissue sites, such as the bone-tendon interface found at the patella. Such combination implants permit reconstruction of sites such as the Anterior Cruciate Ligament (ACL) or Posterior Cruciate Ligament (PCL). According to this embodiment of the invention, a ligament or tendon or skin or collagen sheet membrane is pinned between adjacent blocks of cortical bone. Accordingly, various implants, such as known bone-tendon-bone implants which are in short supply may be supplanted by assemblage of an implant comprising assembled bone blocks, between which is fixed a ligamentous tissue, including but not limited to ligament, tendon, demineralized bone, and the like. Referring to figure 27, there is shown one example of this embodiment of the present invention in which an implant **2700** is assembled from a superior bone block **2701**, an inferior bone block **2702** and a wedged flexible tissue, such as a ligament or tendon or portion of demineralized bone **2704**, all of which are pinned together with cortical bone pins **2703** or other fixation means. Naturally, those skilled in the art will appreciate, based on this disclosure, that other shapes of bone blocks, such as rounded bone blocks, and other types of combinations of soft and hard tissues may be assembled according to this disclosure. However, the example of such an implant **2700** may be used instead of having to harvest a bone-tendon-bone implant from cadaveric knees, which tissue is in short supply.

Based on the present disclosure, those skilled in the art will further appreciate that the cortical bone pins disclosed herein may have features defined thereon for various applications. For example, not meant to be limiting, the shafts may contain stops, such that other pieces of bone inserted thereon can only travel a certain distance down the shaft before encountering the stop. The shaft may also contain through holes, to permit insertion of cotter pins or the like. Furthermore, the cortical bone shaft may be demineralized, mineralized, or partially demineralized. In one specific embodiment, the end of the cortical shaft contains a tapped cannulation a short distance into the longitudinal end of the

shaft. In this way, a screw may be driven into the cannulation to retain elements inserted over the shaft in association with the shaft. To accommodate the screw, the screw end bearing the cannulation may be partially demineralized, such that upon insertion of the retention screw, the shaft end does not shatter, but expands to accommodate the increasing diameter of the screw as it is driven into the shaft. Naturally, in certain applications, it may be desirable for the cortical pins to be cannulated throughout the longitudinal length thereof. However, care should be taken that this does not unduly weaken the overall compressive or torsional strength of the assembled implant. This may be addressed by including pins that are not cannulated, along with pins that are cannulated. The cannulated pins may be used in combination with sutures or the like, in order to hold an implant in a specific orientation, until fusion with adjacent bone has proceeded to a sufficient extent for the implant to become stable without the sutures.

It will be appreciated from the present disclosure that implants that have classically been fabricated from metals may be fabricated by assembling bone pieces. In addition, a benefit of the assembled graft according to this invention is that the components of the assembled graft can be derived from various anatomical structures, thus circumventing limitations normally resulting from having to obtain a graft from a particular anatomical source of a particular donor. Not only can the components be sourced from different anatomies, but also different donors may yield various components for assembly into a unitary implant. The end result is maximization of the gift of donation and the preservation of precious tissue resources. As noted above, being able to pool tissues from different sources depends, to some significant extent, on the ability to treat portions of tissue harvested from different anatomies or donors so as to prevent any contamination of a recipient with pathological or antigenic agents. A further benefit of the present invention is that different implants with height or width limitations due to the anatomical structures from which the implant has been derived may be pinned together to form implants of essentially any desired dimensions. In this fashion, an inventory of building blocks in combination with the appropriate assembly pins, threaded or unthreaded, is useful to provide implants of essentially any dimensions in the course of given surgical procedure. According to this

embodiment of the invention, for example, a cervical Smith-Robinson (CSR) t of any desired height may be produced by attaching two or more existing CSR implants together with cortical bone pins. This is accomplished preferably using two machined CSR's of known height such that when added together, the desired overall height is achieved. The two CSR's are stacked and drill holes are machined through the CSR bodies, following which the cortical bone pins are press-fit through the thus machined holes. Preferably, the diameter of the pins is slightly greater than the diameter of the drilled holes, such that a tight press-fit is achieved.

From the present disclosure, it will further be appreciated that implants according to this invention may be assembled in the operating room by a surgeon, using pre-formed implant pieces, from a kit. It will further be appreciated that the assembled implant pieces may be adhered to each other using any of a number of biologically acceptable glues, pastes and the like. In one such embodiment, the assembled implant pieces are assembled using a polymethyl-methacrylate glue, a cyanoacrylate glue, or any other adhesive known in the art, so long as the use of such an adhesive is confirmed to be non-toxic. It will further be appreciated that in forming the assembled grafts according to the present invention, it is acceptable, although not required, for interlocking features to be included on abutting faces of implant segments to be assembled together. Where such features are included, it is preferred for the adjacent features to be complementary, such that a protrusion on a first surface is met by a compatible indentation in the abutting surface. Such abutting features assist to provide torsional and structural strength to the assembled implant, and to relieve a measure of stress on the cortical bone pins used to assemble the implant.

According to US patent 6,025,538, an elaborate system is disclosed for ensuring that a bore is provided in mating surfaces of a composite implant such that the bore is angularly aligned with respect to mating surfaces so as to be oblique to the plane of each mating surface. This is not required according to the present invention.

According to US patent 5,899,939, layers of bone are juxtaposed, but no mechanical fixation of the various layers to each other is provided for, such as the cortical bone pins disclosed herein.

With respect to PCT Publication WO 00/40177 and the priority US Patent filings, serial nos. 09/225,299, filed 5 January 1999, 09/286,975, filed 6 April, 1999, and 09/368,263, filed 3 August 1999, it is believed that there exists interfering subject matter claimed in the present and in those applications. As to the interfering subject matter, claims are presented herein which are believed to constitute the basis for initiation of an interference proceeding in the United States, and initiation of such a proceeding is hereby specifically elicited, in which it is believed that the present applicants are entitled to priority. As to the non-interfering subject matter disclosed and claimed herein, the right to file one or more continuation or divisional applications free of interfering subject matter is reserved.

Having generally described this invention, including the methods of manufacture and use thereof, including the best mode thereof, those skilled in the art will appreciate that a large number of variations on the principles described herein may be accomplished. Thus, the specifics of this description and the attached drawings should not be interpreted to limit the scope of this invention to the specifics thereof. Rather, the scope of this invention should be evaluated with reference to the claims appended hereto.

WHAT IS CLAIMED IS:

1. A method for manufacture of autograft, allograft and xenograft implants which comprises assembling such implants from smaller pieces of graft materials to form a larger graft implant product.

2. A kit comprising assemblable parts of autograft, allograft and xenograft implants for assembling such implants from smaller pieces of graft materials to form a larger graft implant product which may be formed in the course of a surgical procedure to precisely meet the needs of a given patient or procedure.

3. A method of strengthening or reinforcing autograft, allograft and xenograft implants which comprises assembling such implants from smaller pieces of graft materials to form a larger graft implant product.

4. The method of claim 3 wherein the reinforced product is cancellous bone into which is inserted reinforcing material.

5. The method according to claim 4 wherein said reinforcing material comprises cortical bone.

6. A graft implant comprising any one or combinations of allograft materials, autograft materials, xenograft materials, synthetic materials, metallic materials assembled into a an assembled implant which is assembled into a single graft by use of reinforcing material to hold the constituent pieces of graft materials together.

7. The graft implant according to claim 6 wherein said reinforcing material comprises cortical bone.

8. The graft implant according to claim 6 wherein the assembled implant is pre-treated or treated after assembly to incorporate biologically active or inert materials.

9. An implant comprising segments of cortical bone, cancellous bone, cortical-cancellous bone, or combinations thereof pinned to each other by means of cortical bone pins, wherein, prior to assembly or after assembly, the graft materials are soaked, infused, impregnated, coated or otherwise treated with bone morphogenetic proteins (BMP's), antibiotics, growth factors, nucleic acids, peptides, or combinations thereof.

10. The implant according to claim 6 comprising an assembled cancellous block, or dowel, harvested from the iliac crest or another suitable site to form a Cloward Dowel, iliac crest wedge, or cancellous bone block, dowel, reinforced by insertion therein of cortical bone pins.

11. The implant according to claim 6 comprising a cortical bone implant reinforced by insertion therein of at least one cortical bone pin.

12. The implant according to claim 6 comprising an assembled implant comprising different segments of cortical bone, cancellous bone or both.

13. The implant according to claim 6 comprising an assembled implant comprising different segments of cortical bone, cancellous bone, demineralized cortical or cancellous bone, synthetic material, and combinations thereof.

14. The implant according to claim 13 wherein insertion of reinforcing pins provides an implant with multiple load-bearing pillars.

15. The implant according to claim 14 wherein said pins protrude from the surface of the implant to engage with inferior, superior or both surfaces of bone between which the implant is inserted.

16. The implant according to claim 15 which is a spinal implant.

17. The implant according to claim 15 comprising a cancellous portion of bone implant that has been compression molded, and then affixed to other portions of cortical or cancellous bone machined according to different or similar principles.

18. The implant according to claim 6 in the form of a tapered dowel

19. A method of repairing a bone implant which comprises insertion therein of at least one cortical bone pin.

20. The method according to claim 19 which further comprises affixing a piece of bone to an existing bone implant by affixing said piece of bone to said cortical bone pin.

21. The method according to claim 1 for making an instrument for insertion of other implants.

22. The method according to claim 21 which is an implant driver.

23. A method for salvaging an implant that does not manufacturing specifications which comprises insertion of at least one cortical bone pin at a site to reinforce said site such that in combination with said at least one cortical bone pin, said implant meets manufacturing specifications.

24. An assembled implant comprising a first bone segment pinned to a second bone segment with a flexible tissue affixed between said first bone segment and said second bone segment.

25. The assembled implant according to claim 24 wherein said first and second bone segments are affixed to each other by means of at least one cortical bone pin.

26. A composite bone graft, comprising: a plurality of bone portions layered to form a graft unit, and one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

27. A composite bone graft comprising:
two or more distinct bone portions, and one or more biocompatible connectors, wherein said biocompatible connectors hold together said two or more bone portions to form said composite bone graft, said biocompatible connectors do not comprise an adhesive.

28. A composite bone graft comprising two or more connected, distinct, bone portions, said connected, distinct, bone portions do not comprise an adhesive.

29. A composite bone graft comprising three or more connected, distinct, bone portions, said connected, distinct, bone portions are not connected with an adhesive.

30. The composite bone graft of any one of claim 26, wherein said bone portions are selected from the group consisting of: cortical bone and cancellous bone.

31. A composite bone graft, comprising:
a first bone portion;
a second bone portion;
a third bone portion, said first, second and third bone portions are layered to form a graft unit; and
one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

32. A composite bone graft, comprising:
a first cortical bone portion;
a second cortical bone portion;
a cancellous bone portion disposed between said first cortical bone portion and said second cortical bone portion to form a graft unit; and
one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

33. A composite bone graft, comprising:
a first cortical bone portion;
a second cortical bone portion provided on said first cortical bone to form a graft unit; and one or more biocompatible connectors, connecting said graft unit, said biocompatible connectors do not comprise an adhesive.

34. A composite bone graft, comprising:

a first bone portion;
a second bone portion provided on said first bone portion to form a graft unit; and
one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

35. A composite bone graft, comprising: a plurality of cortical bone portions layered to form a graft unit, and one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

36. A composite bone graft, comprising:
one or more cortical bone portions layered to form a first unit;
one or more cortical bone portions layered to form a second unit;
one or more cancellous bone portions layered to form a third unit; said third unit disposed between said first unit and said second unit to form a graft unit; and
one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

37. A composite bone graft, comprising:
a graft unit having one or more through-holes configured to accommodate one or more pins, said graft unit comprising:
two or more bone portions layered to form said graft unit, and
one or more pins connecting bone portions of said graft unit, said composite bone graft does not comprise an adhesive.

38. The composite bone graft of claim 37, said one or more pins comprising one or more biocompatible materials selected from the group consisting of: cortical bone; stainless steel; titanium; cobalt-chromium-molybdenum alloy; a plastic of one or more members selected from the group consisting of: nylon, polycarbonate, polypropylene, polyacetal, polyethylene, and polysulfone; and one or more bioabsorbable polymers.

39. The composite bone graft of claim 38, said two or more bone portions comprising:
a first bone portion comprising one or more cortical bone portions;
a second bone portion comprising one or more cortical bone portions; and
a third bone portion comprising one or more cancellous bone portions disposed between said first bone portion and said second bone portion to form said graft unit.

40. The composite bone graft of claim 38, said one or more pins comprise one or more cortical bone pins.

41. A composite bone graft, comprising:
a graft unit having one or more through-holes configured to accommodate one or more pins, said graft unit comprising:
a first plate-like cortical bone portion;
a second plate-like cortical bone portion;

a plate-like cancellous bone portion disposed between said first plate-like cortical bone portion and said second plate-like cortical bone portion to form said graft unit, and
one or more cortical bone pins connecting bone portions of said graft unit, said composite bone graft does not comprise an adhesive.

42. A composite bone graft, comprising:
a graft unit having one or more through-holes configured to accommodate one or more pins, said graft unit comprising:
a first plate-like bone portion;
a second plate-like bone portion provided on said first plate-like bone to form said graft unit, and
one or more bone pins for holding together said graft unit, said composite bone graft does not comprise an adhesive.

43. A method for restoring vertical support of the posterior column, comprising implanting a composite bone graft comprising two or more distinct bone portions held together by one or more biocompatible connectors, at a site in a patient.

44. A composite bone graft, comprising:
a graft unit having one or more through-holes configured to accommodate one or more pins, said graft unit comprising:
two or more bone portions layered to form said graft unit,
one or more pins connecting said bone portions of said graft unit, and
a centrally located through-hole disposed perpendicular to interfaces of layered bone portions of said graft unit, said composite bone graft does not comprise an adhesive.

45. A method for making a composite bone graft for implantation into a patient, comprising:
stacking two or more parallel bone planks to form a graft unit;
providing one or more through-holes in said graft unit perpendicular to I interfaces of bone planks;
connecting said two or more parallel bone planks of said graft unit with one or more pins disposed in said one or more through-holes to form a pinned graft unit; and
shaping said pinned graft unit to form said composite bone graft.

46. A composite bone graft, comprising:
one or more cortical bone portions layered to form a first unit;
one or more cortical bone portions layered to form a second unit;
one or more demineralized cancellous bone portions layered to form a third unit; said third unit disposed between said first unit and said second unit to form a graft unit; and
one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

47. A composite bone graft, comprising:

one or more cortical bone portions layered to form a first unit;
one or more cortical bone portions layered to form a second unit;
one or more demineralized cortical bone portions layered to form a third unit; said third unit disposed between said first unit and said second unit to form a graft unit; and
one or more biocompatible connectors for holding together said graft unit, said biocompatible connectors do not comprise an adhesive.

49. A composite bone graft, comprising:
a first unit comprising one or more bone portions;
a second unit connected to said first unit, comprising one or more bone portions; and
one or more biocompatible connectors for connecting said first unit and said second unit, wherein said first unit and said second unit are not in physical contact and define a void therebetween, said biocompatible connectors do not comprise an adhesive.

50. A composite bone graft, comprising: two or more distinct interlocking cortical bone portions.

51. A composite bone graft, comprising: two or more distinct adjacent bone portions where adjacent bone portions are configured to interlock with each other.

52. A composite bone graft, comprising: two or more distinct adjacent bone portions where adjacent bone portions are configured to interlock with each other, and one or more locking pins partially or entirely traversing a dimension of said composite bone graft.

53. A composite bone graft, comprising: two or more distinct adjacent bone portions where adjacent bone portions are configured to interlock with each other to form an interlocked graft unit, said interlocked graft unit is self-locking.

54. A composite bone graft, comprising: two or more distinct adjacent bone portions, said distinct adjacent bone portions comprising complementary peg-like protrusions and corresponding depressions, said protrusions and depressions interlock to provide an interlocking fit between said adjacent bone portions.

55. A composite bone graft, consisting essentially of: two or more distinct adjacent bone portions where adjacent bone portions are configured to interlock with each other.

56. A composite bone graft, consisting essentially of: two or more distinct adjacent bone portions, said distinct adjacent bone portions comprising complementary peg-like protrusions and corresponding depressions, said protrusions and depressions interlock to provide an interlocking fit between said adjacent bone portions.

57. A composite bone graft, consisting essentially of: two or more distinct adjacent bone portions, said distinct adjacent bone portions comprising complementary peg-like

protrusions and corresponding depressions, said protrusions and depressions interlock to provide an interlocking fit between said adjacent bone portions; and one or more locking pins partially or entirely traversing a dimension of said composite bone graft.

58. A composite bone graft, consisting essentially of: two or more distinct adjacent bone portions where adjacent bone portions are configured to interlock with each other, and one or more locking pins partially or entirely traversing a dimension of said composite bone graft.

59. A composite bone graft, comprising: two or more distinct adjacent bone portions where adjacent bone portions are configured to interlock with each other to form an interlocked graft unit, and one or more locking pins traversing a dimension of said composite bone graft, to lock said interlocked graft unit.

60. A composite bone graft, comprising: two or more distinct interlocking bone portions, said interlocking bone portions are self-locking.

61. A composite bone graft, comprising: two or more distinct interlocking bone portions, and one or more locking pins to lock said interlocking bone portions.

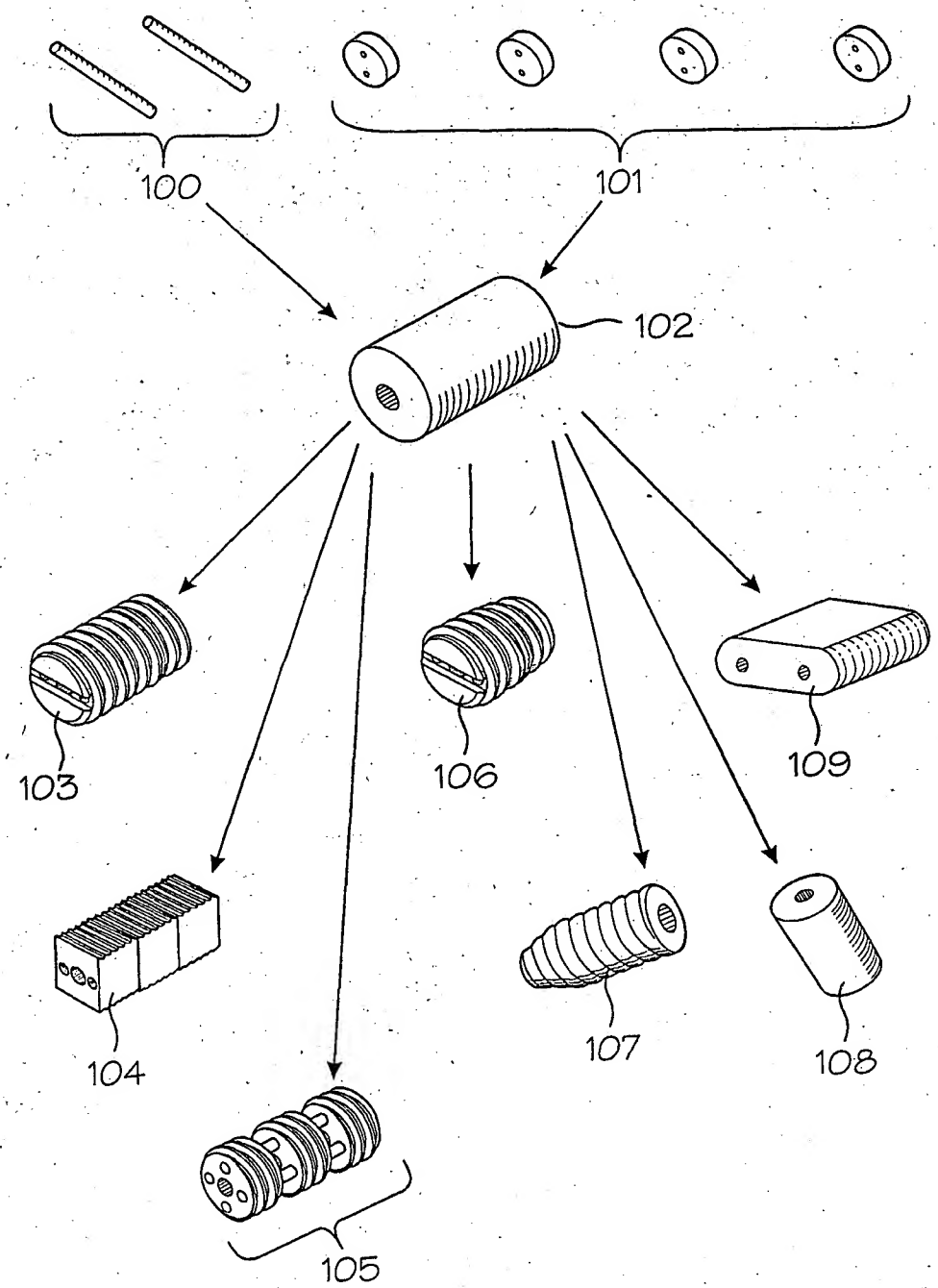
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Fig. 2A

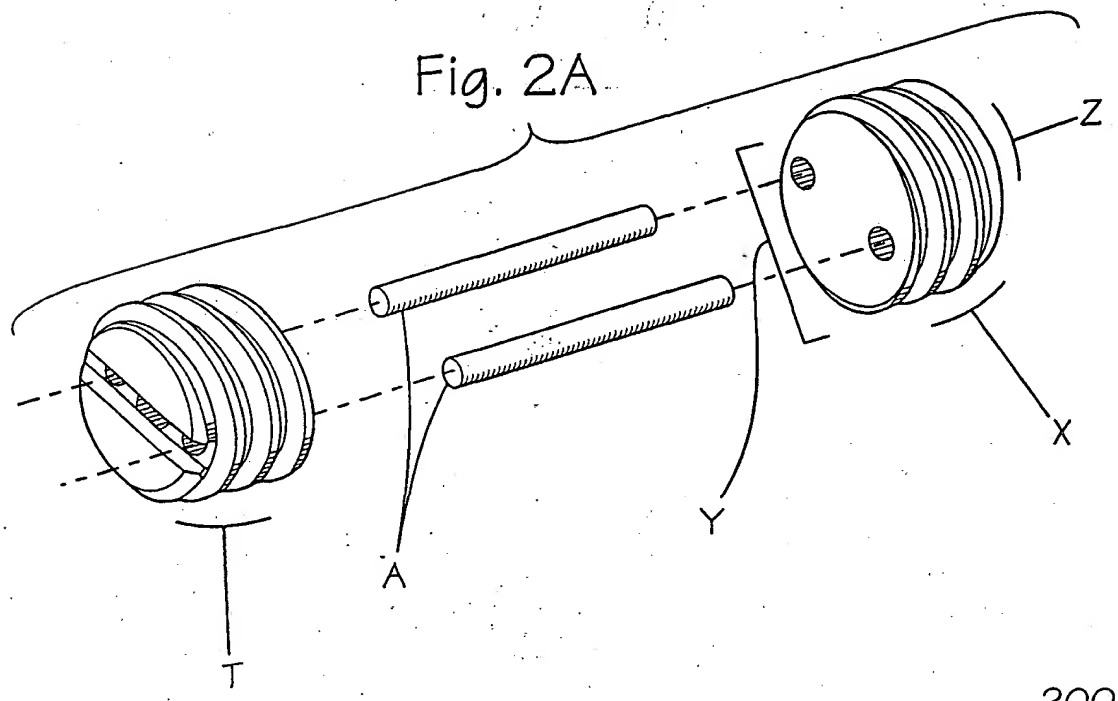


Fig. 2B

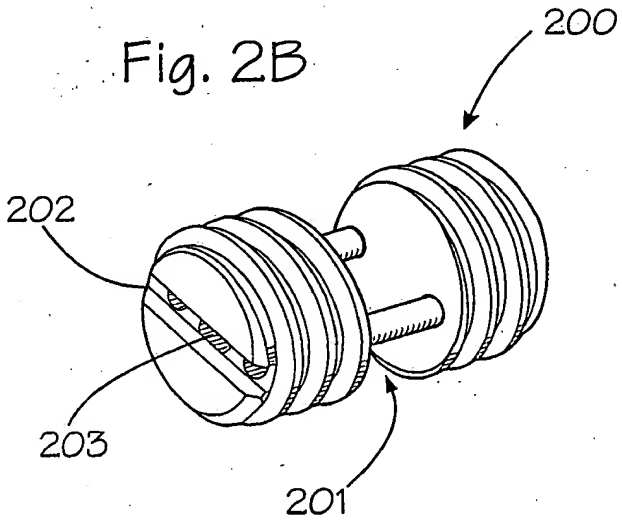


Fig. 3

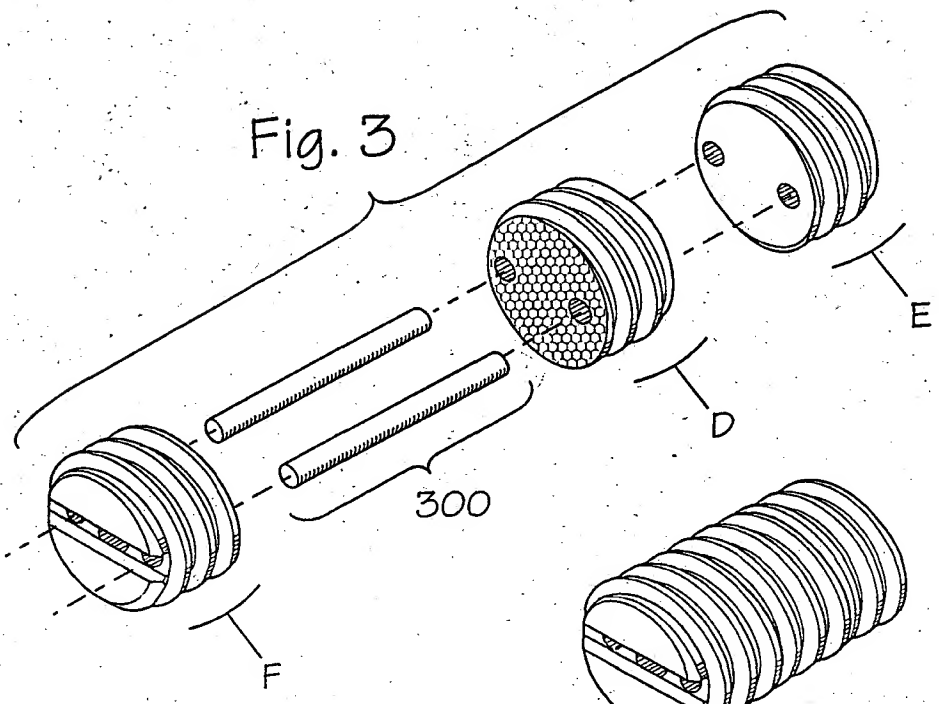


Fig. 4

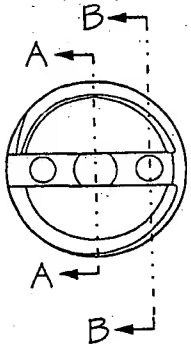


Fig. 5

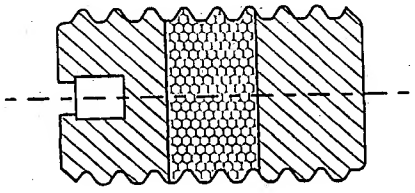


Fig. 6

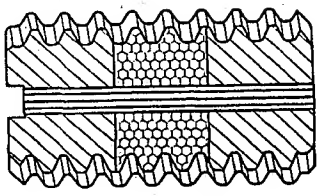


Fig. 7

Fig. 8

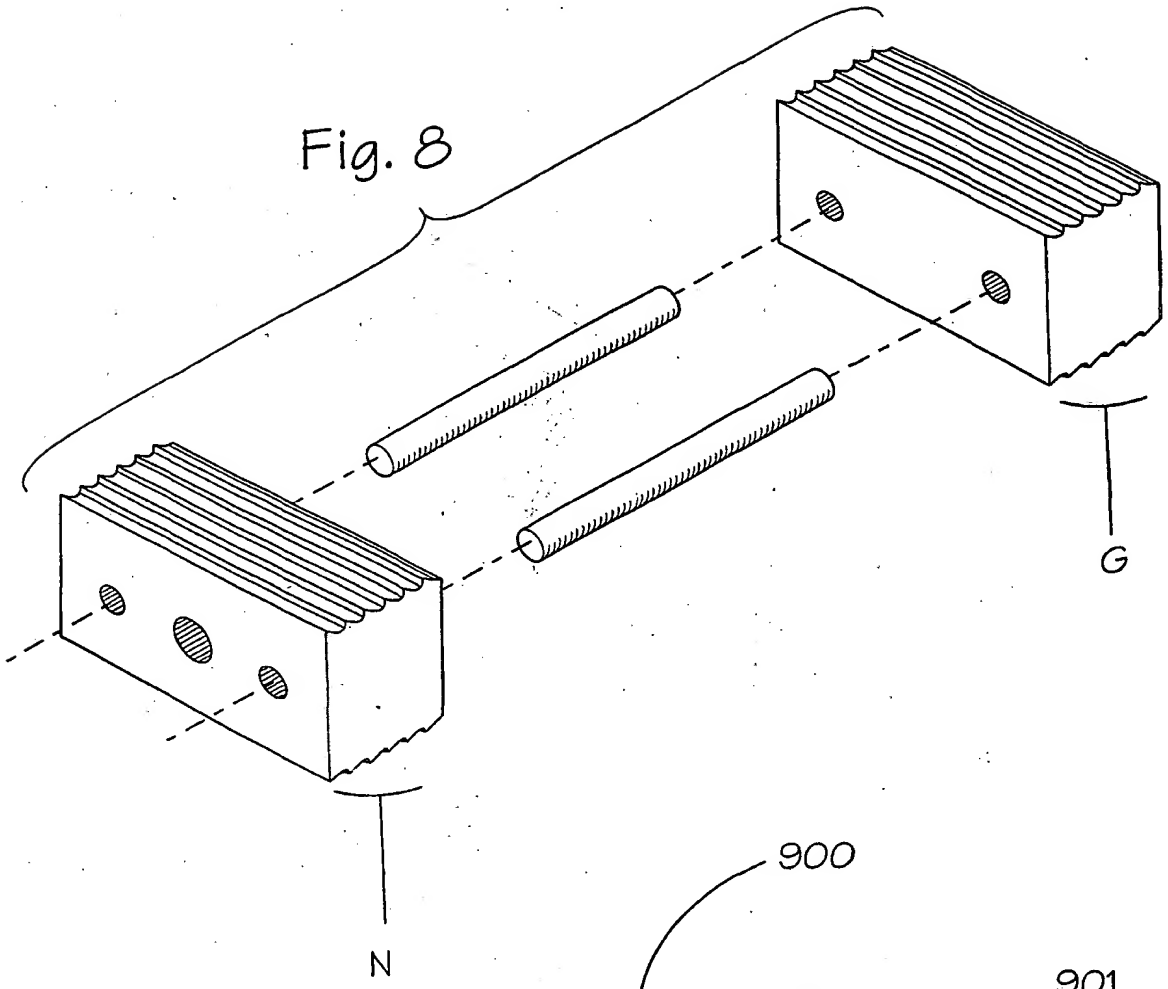


Fig. 9

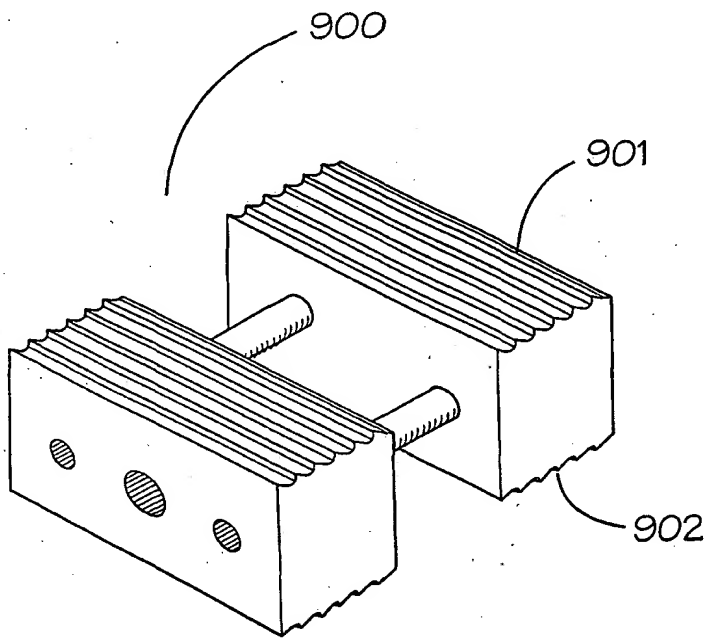
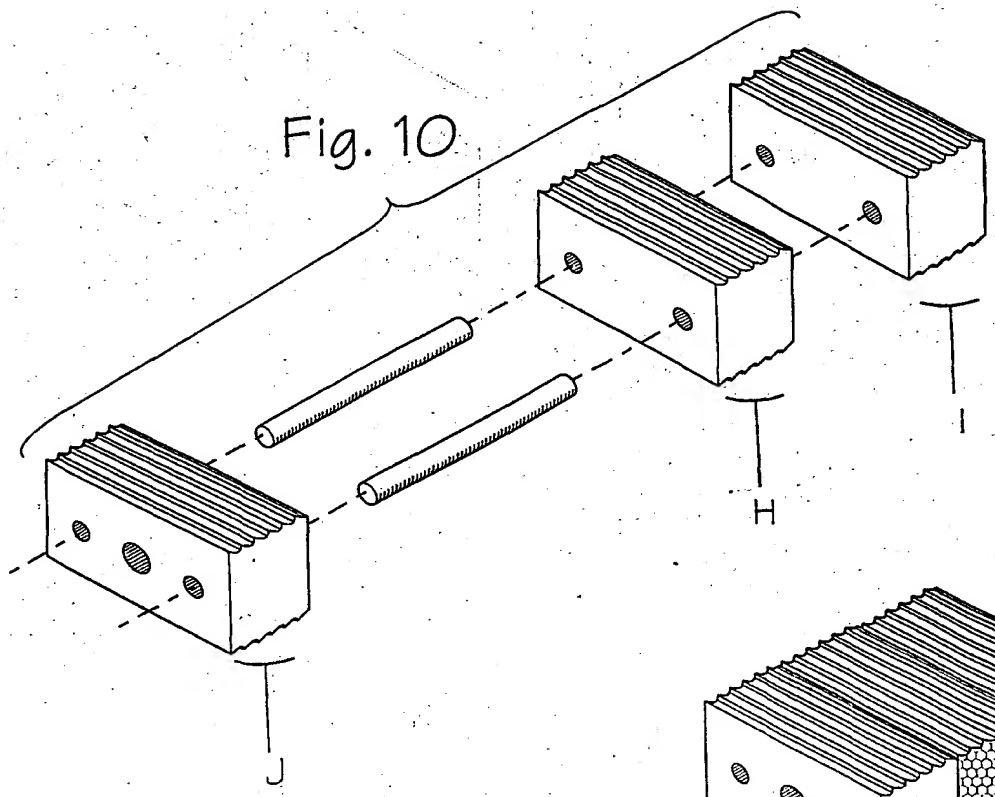


Fig. 10



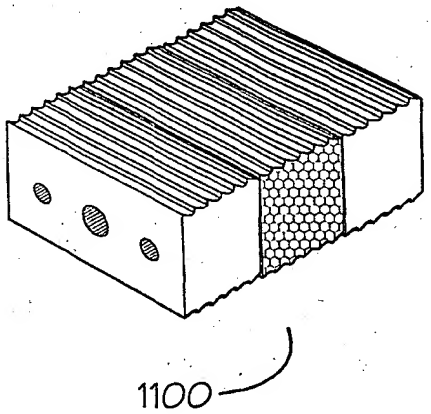


Fig. 11

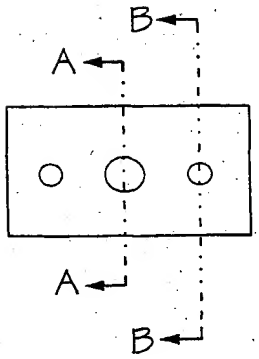


Fig. 12

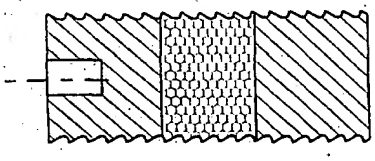


Fig. 13

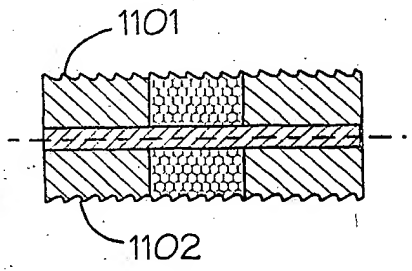


Fig. 14

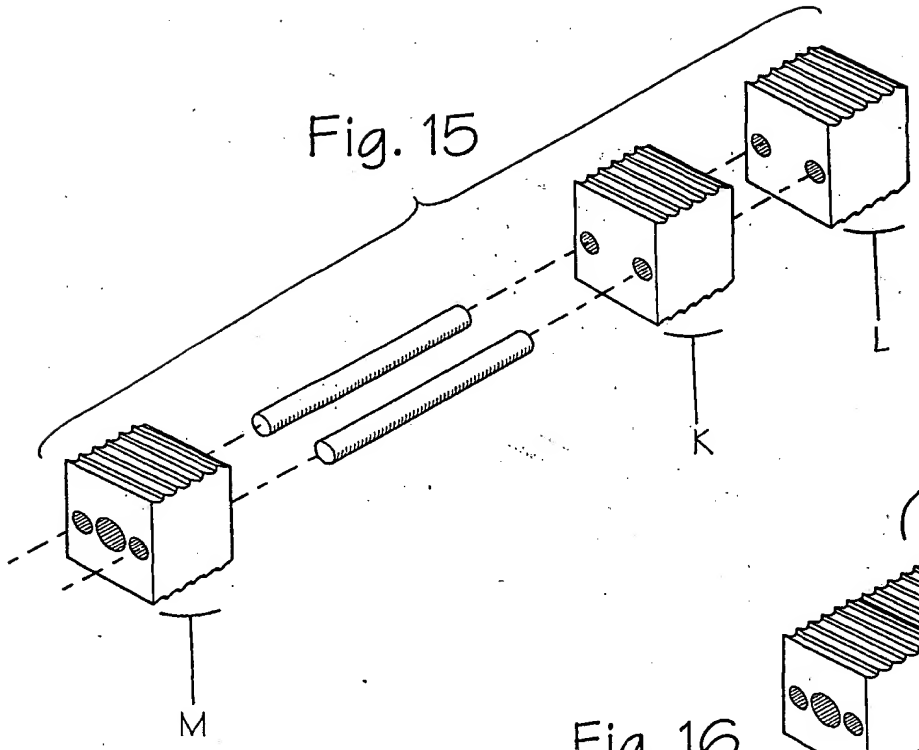


Fig. 15

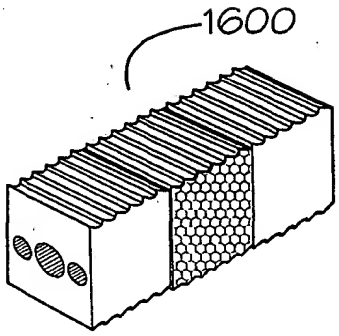


Fig. 16

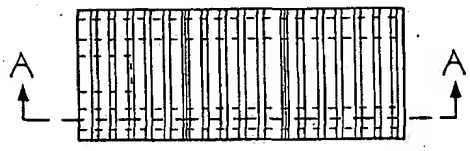


Fig. 17

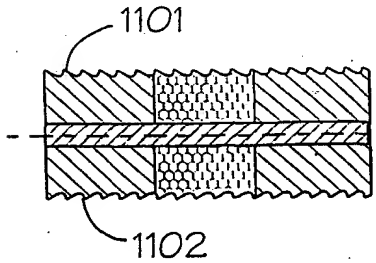
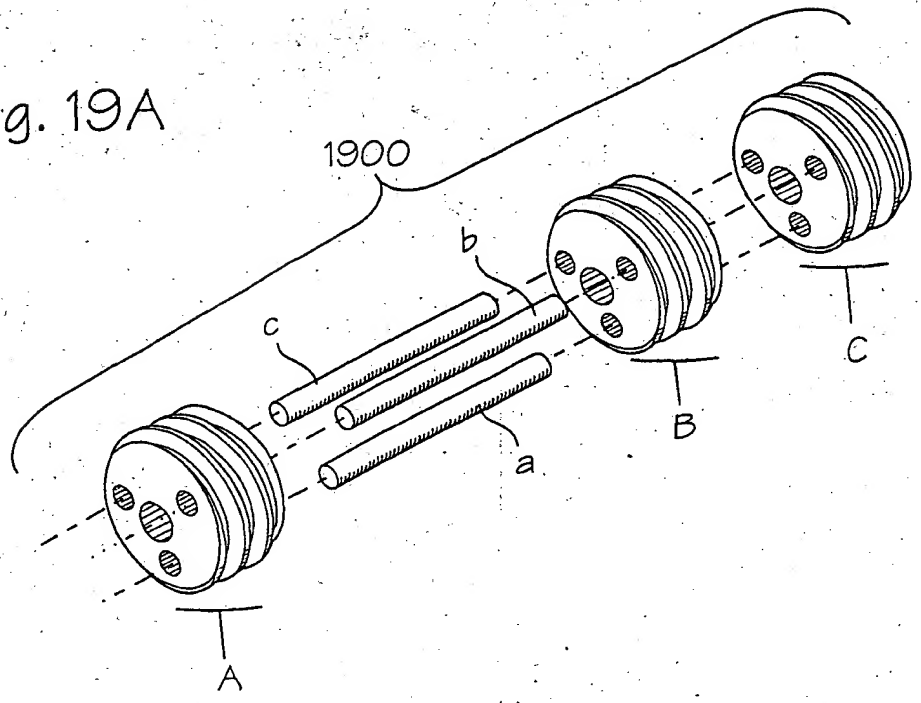


Fig. 18

Fig. 19A



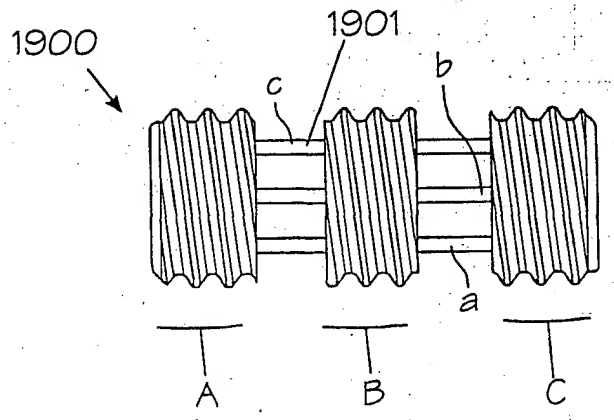


Fig. 19B

Fig. 20A

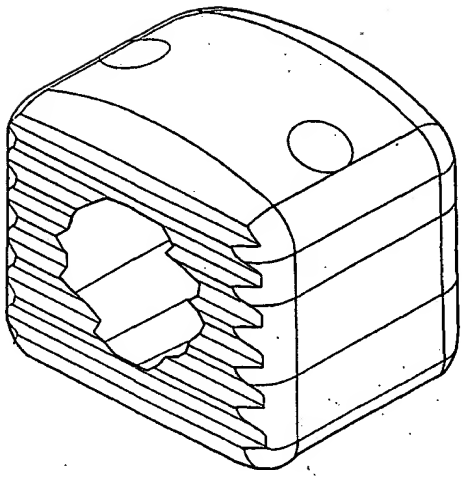


Fig. 20B

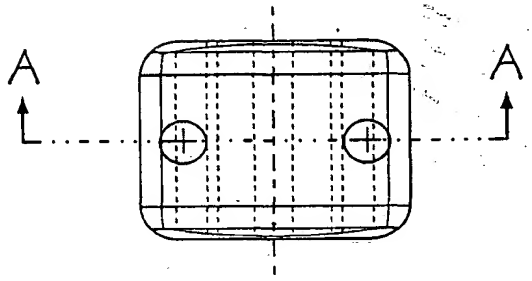


Fig. 20C

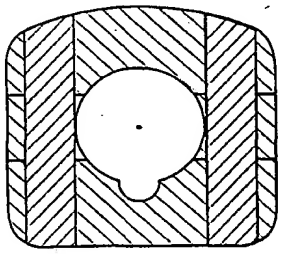


Fig. 20D

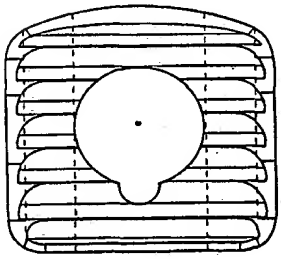


Fig. 20E

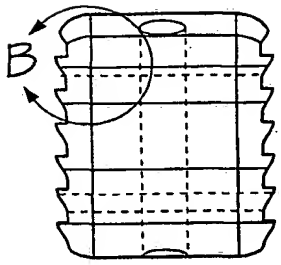


Fig. 20F

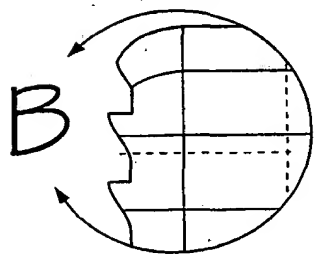
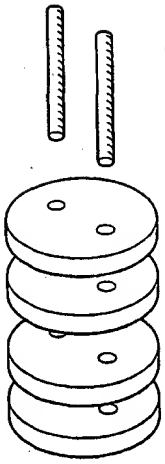


Fig. 20G



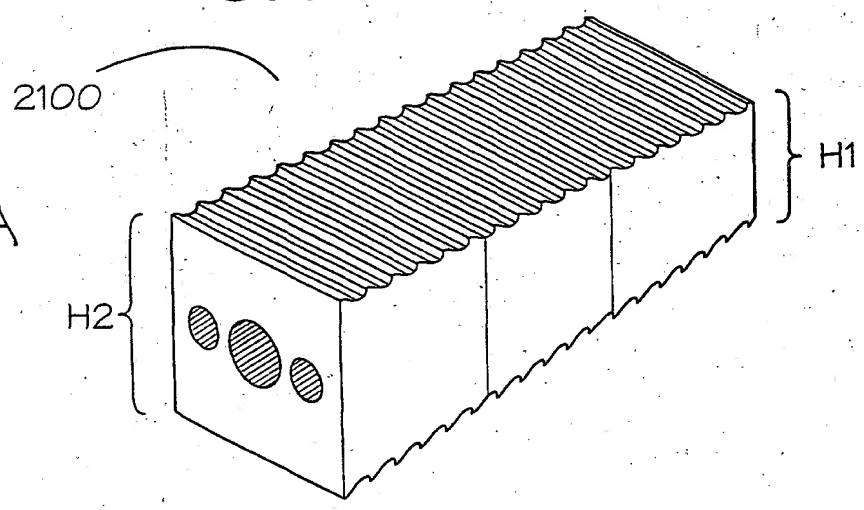


Fig. 21A

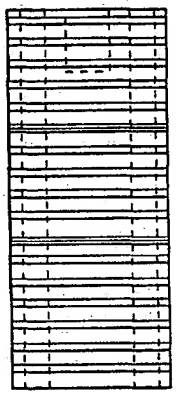


Fig. 21B

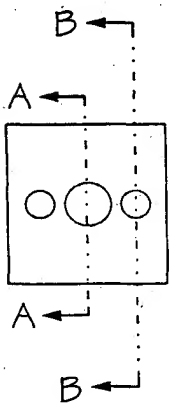


Fig. 21C

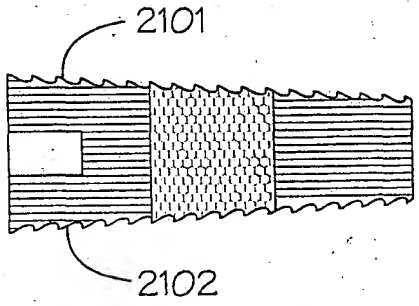


Fig. 21D

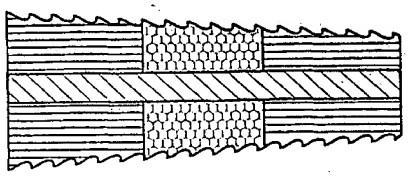
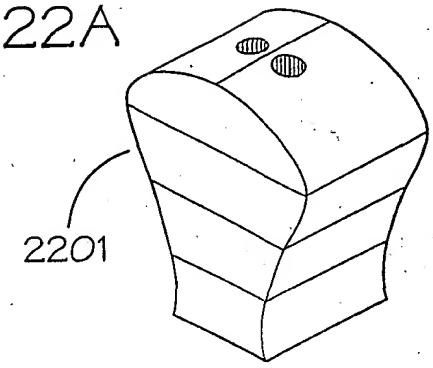


Fig. 21E

Fig. 22A



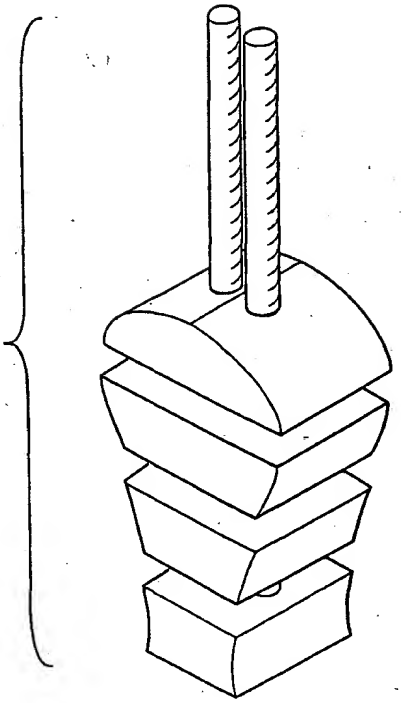
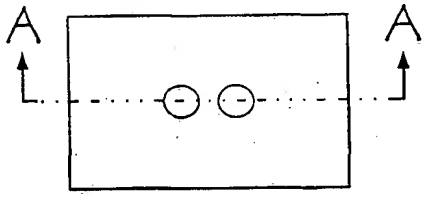


Fig. 22B

Fig. 22C



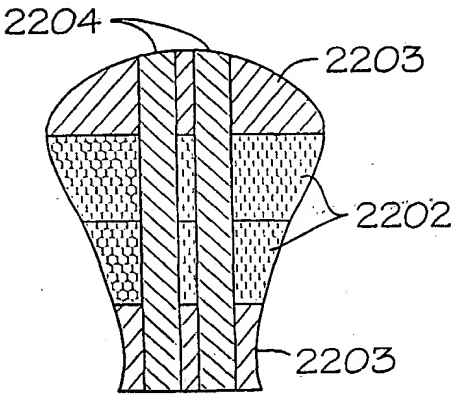


Fig. 22D

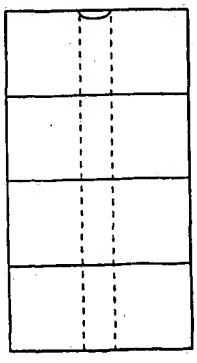
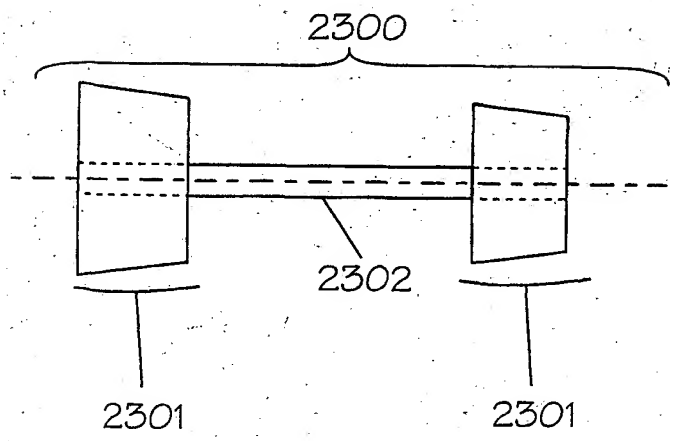


Fig. 22E

Fig. 23



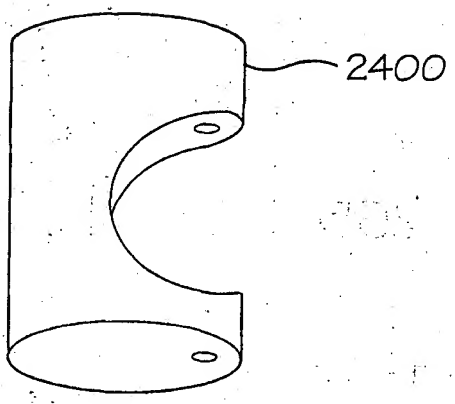


Fig. 24A

Fig. 24B

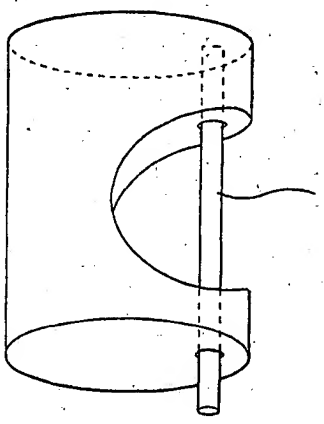
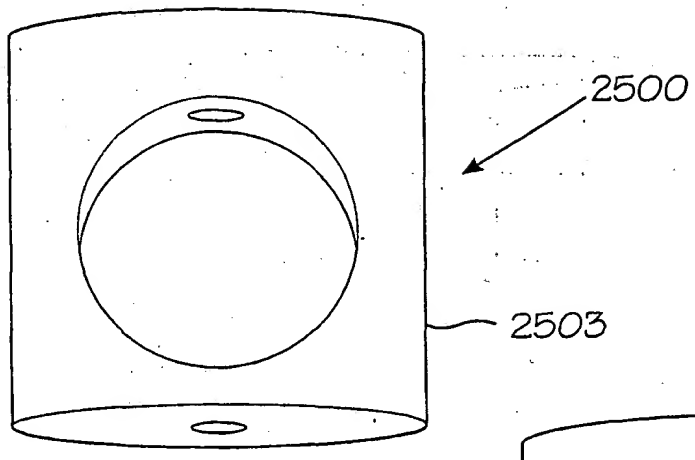


Fig. 25A



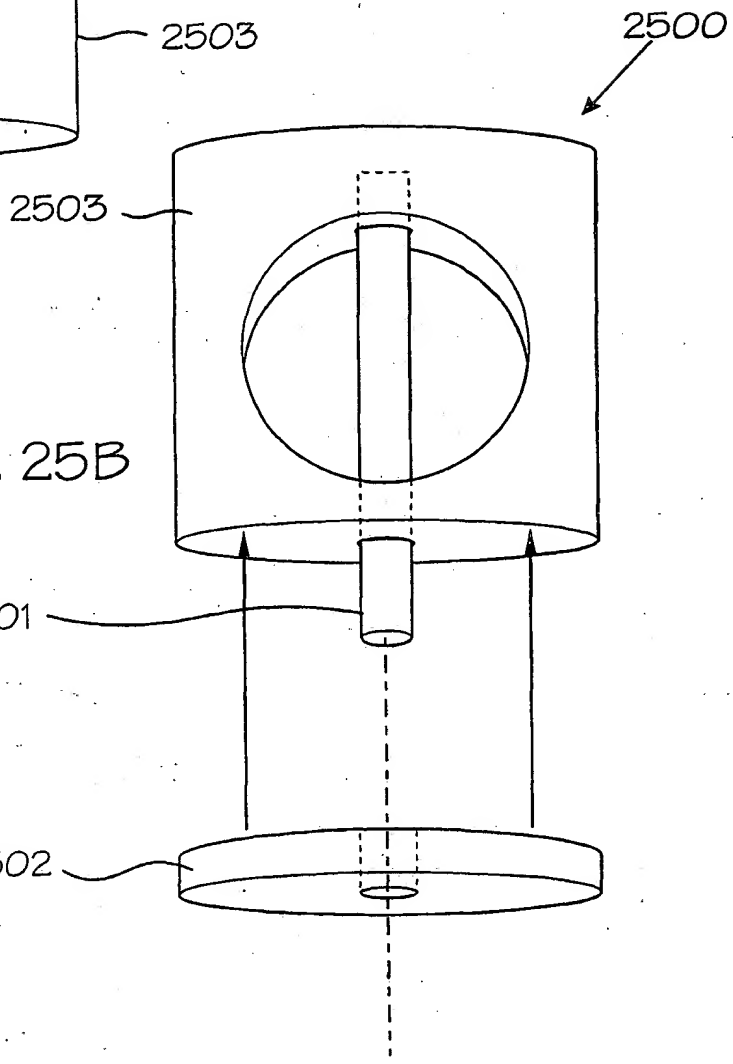


Fig. 25B

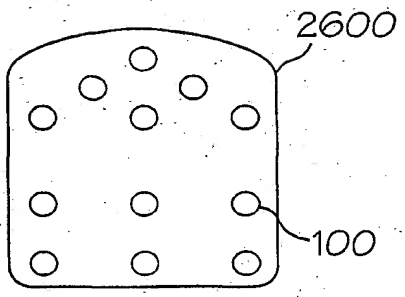


Fig. 26A

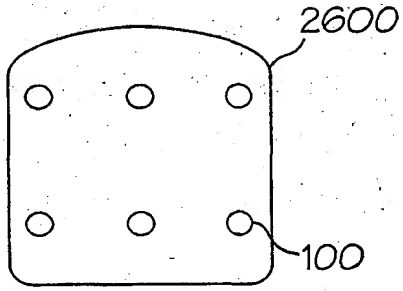


Fig. 26B

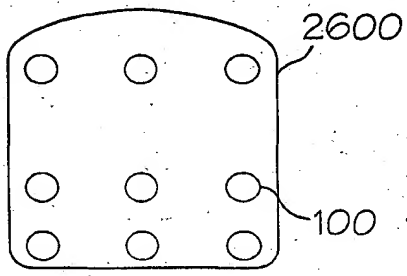


Fig. 26C

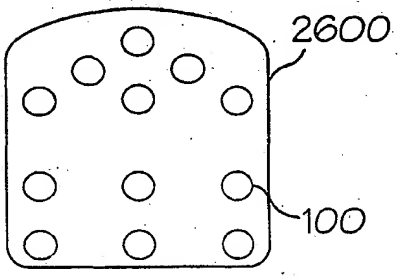


Fig. 26D

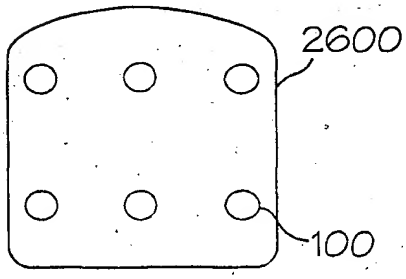


Fig. 26E

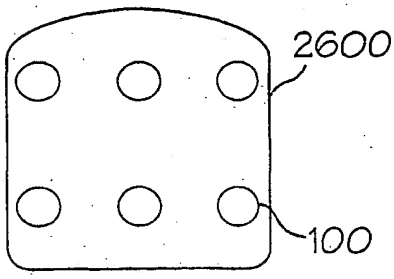


Fig. 26F

14/14

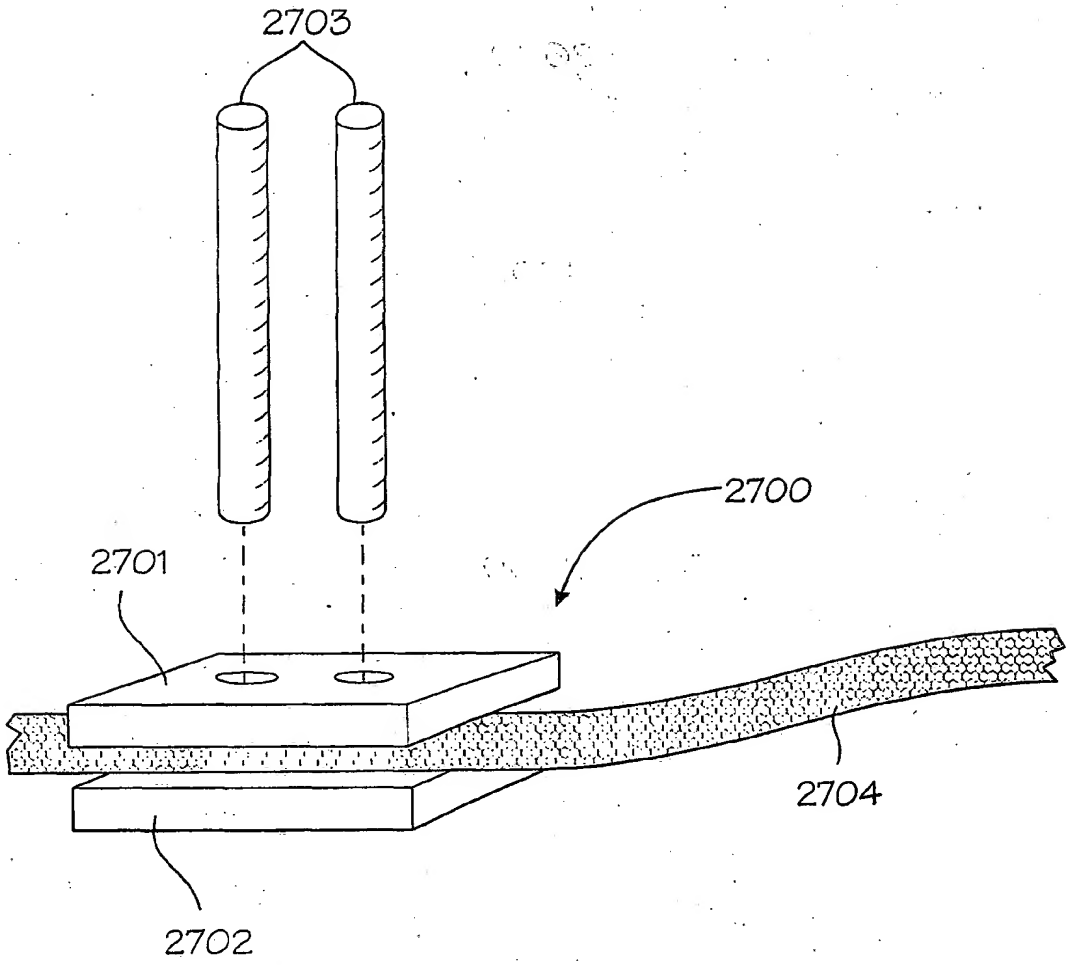


Fig. 27

INTERNATIONAL SEARCH REPORT

Inte ıal Application No
PCT/US 01/04510

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61L27/36 A61F2/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61F A23L A61L A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, MEDLINE, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 676 700 A (SEREKIAN PAUL ET AL) 14 October 1997 (1997-10-14) column 4, line 14 - line 47 figures claims	1-8,12, 13
X	GIE G A ET AL: "CONTAINED MORSELIZED ALLOGRAFT IN REVISION TOTAL HIP ARTHROPLASTY SURGICAL TECHNIQUE" ORTHOPEDIC CLINICS OF NORTH AMERICA,GB,W.B.SAUNDERS CO., LONDON, vol. 24, no. 4, October 1993 (1993-10), pages 717-725, XP000893104 ISSN: 0030-5898 "Preparation of the graft" page 719 figures 3,4,8	1-7,21, 22

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[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

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'X' document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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'&' document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 June 2001	05/07/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/US 01/04510

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 00 40177 A (LIFENET) 13 July 2000 (2000-07-13) cited in the application figures claims	1-61
P,X	US 6 025 538 A (YACCARINO III JOSEPH A) 15 February 2000 (2000-02-15) cited in the application figures claims	1-61
P,X	WO 00 29037 A (HANSTKE SEAN ;REGENERATION TECHNOLOGIES INC (US); MILLS C RANDAL () 25 May 2000 (2000-05-25) cited in the application page 24, line 13 -page 25, line 2 page 26, line 8 -page 27, line 2 claims	1-61
P,X	US 5 899 939 A (BOYCE TODD M ET AL) 4 May 1999 (1999-05-04) cited in the application figures claims	1-61

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Inte nal Application No
PCT/US 01/04510

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WO 0029037 A	25-05-2000	AU 2344500 A	05-06-2000
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